Annexe 1
13th Annual Congress of the European College of Sport Science, p.550, 2008

Automatic detection of key events during the takeoff phase of ski jumps using body fixed inertial sensors

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INTRODUCTION: Takeoff is one of the most important phases of ski jumping. It is then of particular interest to study meaningful kinematics parameters relating the takeoff movements to the overall performance. This requires to precisely identify key events such as when the takeoff movement is initiated (TS), when the toe leaves the ground (TO) or when the ski jumper achieved his final flight posture (TE). Unfortunately, this proved to be impractical using common equipment (i.e. video cameras). In this paper, we propose an ambulatory system that records the accelerations and the angular velocities of ski jumpers' segments during jumps. Based on these signals, we then automatically extract three key events during takeoff: TS, TO and TE. We use these instants to derive timing information during takeoff in hill jumps.
METHODOLOGY: We first carried out in-lab measurements on 5 ski jumpers using a wheeled board on a 5m platform with an inclination of 5deg. Each jump was recorded using an optical motion capture system (VICON, 200Hz) considered as the reference. The key events TS_ref, TO_ref and TE_ref were then manually labeled using both the 3D reconstructions of the simulation jumps and the angle curves. In parallel, the athletes were equipped with 3D inertial modules placed on the thighs and the shanks. Each module was composed of one triaxial gyroscope, one triaxial accelerometer and an embedded datalogger recording the signals at 200Hz. The X-axis was defined as pointing towards the left, Y-axis as pointing upward and Z-axis as pointing forward. TS events were automatically identified by detecting peaks on the thighs angular velocities around the X-axis (pitch); TO events by detecting peaks on the shanks accelerations along the Y-axis and TE by detecting peaks in the shanks angular velocities around the Y-axis (roll). Finally, we applied our ambulatory system in real conditions on the Einsiedeln (Switzerland) medium jumping hill (hs-77 m) and determined takeoff duration (TO-TS) and spring movement duration (TE-TS).
RESULTS AND DISCUSSION: A total of 40 simulation jumps and 3 hill jumps were obtained. We compared our results to the reference (VICON + manual labeling). The standard deviation (SD) between TO and TO_ref was 15ms with a mean error (ME) of -12ms. The SD between TE and TE_ref was 29ms with a ME of 20ms. Finally, the SD between TS and TS_ref was 63ms with a ME of -6ms. This larger latter error may be explained by the fact that it is difficult to precisely determine when the thighs start to rotate even using angles curves. We finally applied our system in real conditions measuring 3 hill jumps. The average takeoff duration was 330ms. The average spring duration was 377ms.
CONCLUSION: we have proposed a new method using inertial sensors to automatically determine key events during takeoff. We validated our system in-lab and applied it on hill jumps to derive important timing information during takeoff.